

Experimental modeling of the chemical remanent magnetization and Thellier procedure on titanomagnetite-bearing basalts

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Abstract

© 2017, Pleiades Publishing, Ltd. The results of the experimental studies on creating chemical and partial thermal remanent magnetizations (or their combination), which are imparted at the initial stage of the laboratory process of the oxidation of primary magmatic titanomagnetites (Tmts) contained in the rock, are presented. For creating chemical remanent magnetization, the samples of recently erupted Kamchatka basalts were subjected to 200-h annealing in air in the temperature interval from 400 to 500°C under the action of the magnetic field on the order of the Earth's magnetic field. After creation of this magnetization, the laboratory modeling of the Thellier-Coe and Wilson-Burakov paleointensity determination procedures was conducted on these samples. It is shown that when the primary magnetization is chemical, created at the initial stage of oxidation, and the paleointensity determined by these techniques is underestimated by 15–20% relative to its true values.

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Keywords

chemical remanent magnetization, oxidation, paleointensity, Thellier procedure, titanomagnetites

References

- [1] Akimoto, T., Kinoshito, H., and Furuta, T., Electron microprobe study on processes of low-temperature oxidation of titanomagnetite, *Mar. Geol.*, 1984, vol. 71, pp. 263–278.
- [2] Alypova, O.M., Thermomagnetic studies of young volcanics of Kamchatka and some regularities in the variations of the magnetic characteristics as function of the composition and formation conditions of the rocks, Extended Abstract of Cand. Sci. (Phys.-Math.) Dissertation, Moscow: Moscow State Univ., 1969.
- [3] Belokon', V.I., Sopka, I.V., and Semkin, S.V., Formation of chemical remanent magnetization during the growth of spontaneous magnetization of reaction products, in *Khimicheskaya namagnichennost': teoriya i eksperiment. Sb. nauch. tr. (Chemical Magnetization: Theory and Experiment. Collection of Scientific Papers)*, Vladivostok: Dal'nevost. Univ., 1991, pp. 3–14.
- [4] Borisova, G.P. and Sholpo, L.E., Chemical magnetization of titanomagnetite at the different stages of its formation, in *Khimicheskaya namagnichennost': teoriya i eksperiment. Sb. nauch. tr. (Chemical Magnetization: Theory and Experiment. Collection of Scientific Papers)*, Vladivostok: Dal'nevost. Univ., 1991, pp. 15–26.
- [5] Bowles, J.A., Tatsumi-Petrochilos, L., Hammer, J.E., and Brachfeld, S.A., Multicomponent cubic oxide exsolution in synthetic basalts: temperature dependence and implications for magnetic properties, *J. Geophys. Res.*, 2012, vol. 117, B03202. doi 10.1029/2011JB008867

- [6] Burakov, K.S., The method for determining the intensity of the geomagnetic field from the curves of thermal demagnetization J_n and J_{rt} , *Materialy IX konferentsii po voprosam postoyannogo geomagnitnogo polya, magnetizma gornykh porod i paleomagnetizma* (Proc. IX Conf. on Constant Geomagnetic Field, Rock Magnetism, and Paleomagnetism), Baku, 1973, vol. 2, pp. 56-57.
- [7] Coe, R.S., The determination of paleointensities of the Earth's magnetic field with special emphasize on mechanisms which could cause nonideal behavior in Thellier method, *J. Geomagn. Geoelectr.*, 1967, vol. 19, no. 3, pp. 157-179.
- [8] Coe, R.S., Gromme, C.S., and Mankinen, E.A., Geomagnetic paleointensities from radiocarbon-dated lava flows on Hawaii and the question of the Pacific nondipole low, *J. Geophys. Res.*, 1978, vol. 83, no. B4, pp. 1740-1756.
- [9] Day, R., Fuller, M., and Schmidt, V.A., Hysteresis properties of titanomagnetites: grain-size and compositional dependence, *Phys. Earth Planet. Inter.*, 1977, vol. 13, no. 4, pp. 260-267.
- [10] Draeger, U., Prevot, M., Poidras, T., and Riisager, J., Single-domain chemical, thermochemical and thermal remanences in a basaltic rock, *Geophys. J. Int.*, 2006, vol. 166, no. 1, pp. 12-32.
- [11] Glevasskaya, A.M., *Magnitnye mineraly i magnetizm vulkanitov* (Magnetic Minerals and Magnetism of Volcanics), Kiev: Nauk. Dumka, 1983.
- [12] Gribov, S.K., The processes of single phase oxidation and subsequent exsolution of titanomagnetites and their role in rock magnetism and paleomagnetism, *Cand. Sci. (Phys.- Math.) Dissertation*, Moscow: OIFZ RAN, 2004.
- [13] Gribov, S.K. and Dolotov, A.V., To the influence of thermochemical magnetization of titanomagnetite-bearing basalts on the results of paleointensity determination by the Thellier technique, 15 *mezhdunarodnaya konferentsiya "Fiziko-khimicheskie i petrofizicheskie issledovaniya v naukakh o Zemle," materialy konferentsii* (Proc. 15th Int. Conf. "Physicochemical and Petrophysical Studies in the Earth Science"), Moscow: IGEM RAN, 2014a, pp. 51-54.
- [14] Gribov, S.K., Dolotov, A.V., and Tsel'movich, V.A., Peculiarities of magnetomineralogical transformation of natural titanomagnetites in air under isothermal conditions, *Uch. Zap. Kazan. Univ., Ser. Estestv. Nauki*, 2014b, vol. 156, book 1, pp. 64-78.
- [15] Haggerty, S.E., Oxidation of opaque mineral oxides in basalts, in *Oxide Minerals. Mineral. Soc. Am. Short Course Notes 3*, Rumble D., Ed., Washington: Geol. Soc. Am., 1976a, pp. Hg1-Hg100.
- [16] Haggerty, S.E., Opaque mineral oxides in terrestrial igneous rocks, in *Oxide Minerals. Mineral. Soc. Am. Short Course Notes 3*, Rumble D., Ed., Washington: Geol. Soc. Am., 1976b, pp. Hg101-Hg300.
- [17] Haggerty, S.E., Oxide textures: a mini-atlas, in *Oxide Minerals: Petrologic and Magnetic Significance*, Lindsley, D.H., Ed., *Reviews in Mineralogy Series*, Washington: Mineral. Soc. Am., 1991, vol. 25, no. 1, pp. 129-219.
- [18] Herrero-Bervera, E. and Valet, J.P., Testing determinations of absolute paleointensity from the 1955 and 1960 Hawaiian flows, *Earth Planet. Sci. Lett.*, 2009, vol. 287, pp. 420-433.
- [19] Khokhlov, A.V. and Shcherbakov, V.P., Palaeointensity and Brunhes palaeomagnetic field models, *Geophys. J. Int.*, 2015, vol. 202, no. 2, pp. 1419-1428.
- [20] Kissel, C. and Laj, C., Improvements in procedure and paleointensity selection criteria (PICRIT-03) for Thellier and Thellier determinations: application to Hawaiian basaltic long cores, *Phys. Earth Planet. Inter.*, 2004, vol. 147, nos. 2-3, pp. 155-169.
- [21] Lindsley, D.H., Experimental studies of oxide minerals, in *Oxide Minerals: Petrologic and Magnetic Significance*, Lindsley, D.H., Ed., *Reviews in Mineralogy Series*, Washington: Mineral. Soc. Am., 1991, vol. 25, no. 1, pp. 69-106.
- [22] Nagata, T., Arai, Y., and Momose, K., Secular variation of the geomagnetic total force during the last 5000 years, *J. Geophys. Res.*, 1963, vol. 68, no. 18, pp. 5277-5281.
- [23] Nguen Tkhi Kim Tkhoa and Pecherskii, D., The signs of chemical magnetization of magnetite formed at titanomagnetite breakdown, *Izv. Akad. Nauk SSSR, Fiz. Zemli*, 1987, no. 5, pp. 69-76.
- [24] Nguyen, T.K.T. and Pechersky, D.M., Experimental study of chemical and crystallization remanent magnetizations in magnetite, *Phys. Earth Planet. Inter.*, 1987, vol. 46, nos. 1-3, pp. 46-63.
- [25] Özdemir, O., Inversion of titanomaghemites, *Phys. Earth Planet. Inter.*, 1987, vol. 46, pp. 184-196.
- [26] Petersen, N., Observation of shrinkage cracks in ocean floor titanomagnetites, *Phys. Earth Planet. Inter.*, 1987, vol. 46, nos. 1-3, pp. 197-205.
- [27] Ramdohr, P., *Die Erzminerale und ihre Verwachsungen*, Berlin: Akad. Verlag, 1955
- [28] Richards, J.C.W., O'Donovan, J.B., Hauptman, Z., O'Reilly, W., and Creer, K.M., A magnetic study of titanomagnetite substituted by magnesium and aluminium, *Phys. Earth Planet. Inter.*, 1973, vol. 7, no. 4, pp. 437-444.
- [29] Selkin, P.A. and Tauxe, L., Long-term variations in palaeointensity, *Philos. Trans. R. Soc. London A*, 2000, vol. 358, no. 1768, pp. 1065-1088.
- [30] Shcherbakov, V.P., Khokhlov, A.V., and Sycheva, N.K., On the distribution function of the geomagnetic field intensity according to the model of a giant Gaussian process and empirical data, *Izv., Phys. Solid Earth*, 2015, no. 5, pp. 768-799.

- [31] Skovorodkin, Yu.P., Studying the formation mechanism of remanent magnetization in lava flows, Extended Abstract of Cand. Sci. (Phys.-Math.) Dissertation, Moscow: Moscow State Univ., 1966.
- [32] Smirnov, A.V. and Tarduno, J.A., Thermochemical remanent magnetization in Precambrian rocks: are we sure the geomagnetic field was weak?, *J. Geophys. Res.*, 2005, vol. 110, B06103.
- [33] Thellier, E. and Thellier, O., Sur l'intensité du champ magnétique terrestre dans le passé historique et géologique, *Ann. Geophys.*, 1959, vol. 15, pp. 285-376.
- [34] Tucker, P. and O'Reilly, W., The laboratory simulation of deuteritic oxidation of titanomagnetites: effect on magnetic properties and stability of thermoremanence, *Phys. Earth. Planet. Inter.*, 1980, vol. 23, no. 2, pp. 112-133.
- [35] Wilson, R.L., The thermal demagnetization of natural magnetic moments in rocks, *Geophys. J. R. Astron. Soc.*, 1961, vol. 5, no. 1, pp. 45-58.
- [36] Wilson, R.L., Palaeomagnetism and rock magnetism, *Earth-Sci. Rev.*, 1966, vol. 1, nos. 2-3, pp. 175-212.
- [37] Yamamoto, Y., Tsunakawa, H., and Shibuya, H., Palaeointensity study of the Hawaiian 1960 lava: implications for possible causes of erroneously high intensities, *Geophys. J. Int.*, 2003, vol. 153, no. 1, pp. 263-276.
- [38] Yamamoto, Y., Possible TCRM acquisition of the Kilauea 1960 lava, Hawaii: failure of the Thellier paleointensity determination inferred from equilibrium temperature of the Fe-Ti oxide, *Earth Planets Space*, 2006, vol. 58, pp. 1033-1044.
- [39] Yamamoto, Y. and Hoshi, H., Paleomagnetic and rock magnetic studies of the Sakurajima 1914 and 1946 andesitic lavas from Japan: a comparison of the LTD-DHT Shaw and Thellier paleointensity methods, *Phys. Earth. Planet. Inter.*, 2008, vol. 167, nos. 1-2, pp. 118-143.